Capuchin Monkey (*Cebus apella*) Grips for the Use of Stone Tools

GREGORY CHARLES WESTERGAARD* AND STEPHEN J. SUOMI
Laboratory of Comparative Ethology, National Institute of Child Health and Human Development, Poolesville, Maryland 20837

KEY WORDS capuchin; hominid; precision grip; power grip; tool use

ABSTRACT This research examined capuchin monkey (*Cebus apella*) grips for the use of throwing, nut-cracking, and cutting tools. We provided subjects with stones and apparatus that accommodated the use of stones as tools. Our subjects exhibited five grips, two of which the animals used when force was the primary consideration (power grips) and three of which the animals used when accuracy of sensory judgment and instrumentation was required (precision grips). We believe that the range of contexts in which capuchins use stone tools, combined with the ability of capuchins to employ both power and precision grips as part of their tool repertoire, indicate that *Cebus apella* can be used to identify grips that facilitated hominid lithic technology. Am J Phys Anthropol 103:131–135, 1997. © 1997 Wiley-Liss, Inc.

Several authors have argued that a complete understanding of the relation between manual grips and tool use in extant nonhuman primates would help us to identify potential grips and tool behaviors in fossil hominids (Boesch and Boesch, 1993; Marzke and Wullstein, 1996). Boesch and Boesch (1993) report that chimpanzees exhibit six different grips when they crack open nuts with tools. The range of chimpanzee nut-cracking grips led these authors to postulate that *Pan troglodytes* is morphologically able to perform most tool tasks that have been attributed to *Homo habilis.*

Capuchins are arboreal New World primates whose manipulative skills approach those of chimpanzees (Visalberghi, 1990; Westergaard, 1994). Capuchins use tools in isolated instances in nature, and habitually in captivity when provided with appropriate materials and incentives (Visalberghi, 1990; Westergaard, 1994). Examples of capuchin tool behavior in captivity include aimed throwing of stones, the use of stones as nut-cracking tools, and the use of stone flakes as cutting tools (Anderson, 1990; Westergaard and Suomi, 1994, 1995, 1996). Capuchins lack true thumb opposition as the thumb is incapable of rotation about its own long axis (Napier, 1960). However, capuchins, unlike other New World primates such as squirrel monkeys, use both precision and power grips to manipulate objects (Costello and Fragaszy, 1988). To the best of our knowledge capuchin grips for the use of tools have not been described.

This research examined capuchin grips for the use of throwing (Experiment 1), nut-cracking (Experiment 2), and cutting tools (Experiment 3). We provided subjects with stones and apparatus that accommodated the use of stones as tools and recorded grips using a modified version of the classification scheme outlined by Marzke and Wullstein (1996; see Table 1). We further distinguished between grips used when force was

Contract grant sponsor: National Institute of Child Health and Human Development; Grant name: Intramural Research Training Award.

*Correspondence to: Gregory Charles Westergaard, National Institutes of Health Animal Center, P.O. Box 529, Poolesville, MD 20837. e-mail: WESTERGG@lce.nichd.nih.gov

Received 26 April 1996; accepted 5 March 1997.

TABLE 1. Grips and operational definitions

	Operational definition
Power grips	
Jaw-chuck	Grip in which an object is held tightly against the palm by flexed fingers. The thumb either opposes the fingers or supports the object from the side.
Bimanual jaw-chuck	Jaw-chuck grip in which an object is held by both hands.
Palm push	Grip in which an object is pushed by an open palm.
Precision grips	
Cup	Grip in which an object is cupped in an upturned palm, and propped by flexed fingers and an opposed thumb.
Pad-to-side	Grip in which the thumb props or holds an object against the side of the index finger.
Bimanual tip-to-tip	Grip in which object is held between tips of fingers on each hand.

the primary consideration (power grips) and those used when accuracy of sensory judgment and instrumentation was required (precision grips; Napier, 1960). Our goal in this research was to establish the range of grips required for a simple nonhuman primate stone-tool technology. We chose to examine capuchin grips for the use of stone tools, as opposed to tools made of vegetation or other materials, because stone tools are the most ancient homonid artifacts preserved in the archaeological record (Schick and Toth, 1993).

METHODS

Subjects

The subjects were four tufted capuchins (*Cebus apella*). These animals were chosen as subjects because of their proficient use of tools across a number of different contexts (Westergaard and Suomi, 1994, 1995, 1996). Included were one adult female (Carlina) and three adult males (Morris, Jeb, and Virgil) that ranged in age from 7 to 16 years. Subjects were housed socially in indoor cages (2 × 1 × 2 m). Food and water were available ad libitum.

Throwing

At the onset of each test session we filled a plastic container (15 × 12 cm high) with peanut butter and placed it on the room floor 40 cm from the front of a group's cage. We then placed a video camera (Canon ES2000 Hi-8mm video camcorder) outside the cage directly behind the apparatus. At the onset of each trial we placed a stone (between 20 and 40 g in weight) on the cage floor. An observer noted from videotape grips used by the focal subject to throw a stone towards the container, and whether the stone landed in the container ("hit") or on the room floor ("miss"). We calculated the accuracy rate for each grip using the formula [(number of hits/number of throws) × 100]. We conducted 40 trials per subject over a 2-week period.

Nut-cracking

The apparatus was a plastic container (10 × 10 cm high) with a round opening (2.5 cm in diameter) on top. The apparatus held a walnut in a fixed position. At the onset of each test session we attached the apparatus to the cage floor, placed a video camera outside the cage directly behind the apparatus, and distributed four stones (each between 40 and 60 g in weight) on the cage floor. At the onset of each trial we mounted a walnut in the apparatus so that it protruded through the opening. An observer noted from videotape grips used by the focal subject to crack open a walnut with a stone. If an animal successively struck a walnut with two or more stones the observer only recorded grips used to hold the stone that cracked the walnut's shell. We conducted 40 trials per subject over a 2-week period.

Cutting

The apparatus was a plastic container (10 × 10 cm high) with a square opening (3 × 3 cm) on top. The container held peanut butter in a small well (2 × 1 cm high). At the onset of each test session we attached the apparatus to the cage floor, placed a video camera outside the cage directly behind the apparatus, and distributed four stones (each between 20 and 60 g in weight) on the cage floor. Each stone had at least one sharp edge. At the onset of each trial we placed an acetate barrier over the apparatus so that it covered the well. The animals could only obtain food by cutting through the barrier with a stone. An observer noted from video-

TABLE 2. Capuchin grips for aimed throwing of stones

Subject	Percentage of trials in which subject used this grip			Mean number of grips per trial
	Jaw-chuck	Cup	Pad-to-side	
Carlina	5	95	0	1.0
Jeb	98	0	2	1.0
Morris	100	0	0	1.0
Virgil	95	0	5	1.0
Mean per subject	74	24	2	1.0

TABLE 3. Capuchin grips for nut-cracking with stone tools

Subject	Percentage of trials in which subject used this grip		Mean number of grips per trial
	Jaw-chuck	Bimanual jaw-chuck	
Carlina	95	12	1.1
Jeb	100	0	1.0
Morris	100	10	1.1
Virgil	82	75	1.6
Mean per subject	94	24	1.2

tape grips used by the focal subject to cut through acetate with a stone tool. If an animal successively placed two or more stones in contact with the barrier the observer only recorded grips that the animal used to hold the stone that penetrated the barrier. We conducted 40 trials per subject over a 2-week period.

RESULTS

Throwing

The capuchins used three different grips to throw stones (see Table 2). Four subjects used the jaw-chuck grip in 74% of the overall trials (accuracy rate = 50%). A capuchin typically held a stone against a downturned palm by flexed fingers, and propelled the stone by downward extension of the arm. A second capuchin throwing grip was the cup grip in which an animal held a stone in an upturned palm and propelled the stone by extension of the arm away from the body. One subject used the cup grip in 24% of the overall trials (accuracy rate = 82%). A third capuchin throwing grip was the pad-to-side grip in which an animal held a stone between the thumb and side of the index finger, and propelled the stone by downward extension of the arm. Two subjects used the pad-to-side grip in 2% of the overall trials (accuracy rate = 67%). Subjects used only one type of throwing grip within each trial.

Nut-cracking

The capuchins used two different grips to crack open nuts with stone tools (see Table 3). Four subjects used the jaw-chuck grip in 94% of the overall trials. A capuchin typically held a stone in a downturned palm by flexion of the fingers against an opposed thumb. Involvement of the fourth and fifth digits was dependent upon the size and shape of the stone. Greatest involvement of these digits occurred when an animal used large cylindrical stones. A second capuchin nut-cracking hand posture was the bimanual jaw-chuck grip. Three subjects used this grip in 24% of the overall trials. Capuchins held stones either with hands side-by-side or with one hand overlapping the other. It appeared that subjects used the bimanual jaw-chuck grip to increase the force of the stone on the walnut. The mean number of grips used per trial was 1.2.

Cutting

The capuchins used four different grips to cut through acetate barriers with stone tools (see Table 4). Four subjects used the jaw-chuck grip in 100% of the overall trials. Capuchins used the jaw-chuck grip to place stones against acetate, to push down on stones, and to remove stones from the apparatus. A second capuchin hand posture for cutting was the palm push. Four subjects used this grip in 94% of the overall trials. Capuchins used the palm push to force stones through acetate barriers. A third capuchin hand posture for cutting was the pad-to-side grip. Four subjects used this grip in 24% of the overall trials. Capuchins used the pad-to-side grip to place stones against acetate, to reposition stones during their use, and to remove stones from the apparatus. A fourth capuchin hand posture for cutting was the bimanual tip-to-tip grip. Three subjects used this grip in 7% of the overall trials. Capuchins used the bimanual tip-to-tip grip to remove stones from the apparatus. The mean number of grips used per trial was 2.2. Analysis of variance indicated a significant main effect of task on the mean number of grips per trial ($F(3,2)$ =

TABLE 4. Capuchin grips for cutting with stone tools

Subject	Percentage of trials in which subject used this grip: Jaw-chuck	Palm push	Pad-to-side	Bimanual tip-to-tip	Mean number of grips per trial
Carlina	100	98	10	10	2.2
Jeb	100	88	5	0	1.9
Morris	100	98	68	12	2.8
Virgil	100	90	12	5	2.1
Mean per subject	100	94	24	7	2.2

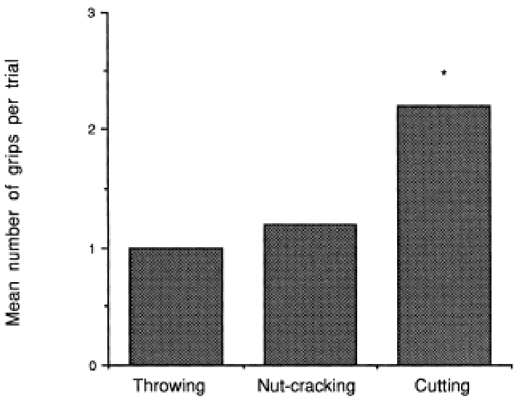

Fig. 1. Mean number of grips per trial exhibited by capuchins for the use of stones as throwing, nut-cracking, and cutting tools. *Mean number of grips for cutting was significantly greater than the mean number of grips for throwing or nut-cracking (Fisher's PLSD test, $P < .05$).

22.86, $P < .05$). Fisher's protected least significant difference (PLSD) post hoc paired comparison test ($P < .05$) indicated that subjects used a greater mean number of grips per trial for cutting than for nut-cracking or throwing (see Fig. 1).

DISCUSSION

Our results indicate that capuchins employ a variety of grips when they use stones for throwing, nut-cracking, and cutting. Our subjects exhibited five grips, two of which the animals used when force was the primary consideration (power grips) and three of which the animals used when accuracy of sensory judgment and instrumentation was required (precision grips; Napier, 1960). We believe that the range of contexts in which capuchins use stone tools, combined with the ability of capuchins to employ both power and precision grips as part of their tool repertoire, indicate that *Cebus apella* can be used to identify grips that facilitated hominid lithic technology (Parker and Gibson, 1977; Westergaard and Suomi, 1994).

Marzke and Wullstein (1996) note three elements of gripping that distinguish humans from chimpanzees. These elements are (1) the relative force of precision grips (pinch vs. hold), (2) the relative ability to translate and rotate objects by the thumb and fingers (precision handling), and (3) the relative ability to orient a cylindrical object so that it functions effectively as an extension of the forearm (power squeeze). Capuchin precision grips were weak relative to those of humans, and did not involve translation or rotation of objects at the joints of the thumb and fingers. Capuchin power grips did not suggest active use of the palm that would facilitate increased forearm leverage when using an object as an extension of the arm. Preliminary studies of grips by orangutans (Marzke and Wullstein, personal observation), baboons (Guthrie, 1991; Jude, 1993, cited in Marzke and Wullstein, 1996), and capuchins (Costello and Fragaszy, 1988) indicate a lack of these gripping elements in *Pongo, Papio,* and *Cebus*, providing further evidence that precision grip force, precision grip maneuverability, and power squeeze of cylinders differentiate the gripping behavior of humans from that of great apes and monkeys.

Given the apparent discontinuity between humans and nonhuman primates concerning gripping, it is noteworthy that capuchins, particularly because of the pseudo-opposable status of their thumbs, employ a range of power and precision grips when they use tools. Our results indicate that ballistic movements such as those involved in throwing and nut-cracking require a more limited range of grips than do the more precise movements involved in cutting. There

is little direct evidence indicating the range of contexts in which early hominids used tools, although it is believed that stones were used for throwing, nut-cracking, and cutting (Schick and Toth, 1993). Susman (1994) has noted that the earliest Australopithecines, who had ape-like thumbs, did not leave behind evidence of a lithic technology but that species with a human-like thumb (for example, *Paranthropus robustus*) did. The rationale underlying this argument is that long stout thumbs facilitated refined precision grasps and production of artifacts that are recognizable in the archaeological record. Capuchins and bonobos produce simple stone tools by striking stones against hard surfaces using actions similar to those involved in nut-cracking with stones (Toth et al., 1993; Westergaard and Suomi, 1994). Precise human-like finger movements are simply not required for this aspect of tool behavior. Similarities in tool-using propensities between capuchins, apes, and hominids have been attributed to convergent processes (Westergaard and Suomi, 1994), and the extent to which the hand and wrist morphology of *Cebus* differentiates the tool-behavior of capuchins from that of humans remains to be determined. We believe that the data presented in this report are consistent with Napier's (1962) assertion that the ability to form a precision grip is not an essential requisite for use and production of simple stone tools, and Susman's (1995) assertion that the earliest hominid technology emerged prior to the development of true thumb opposition and corresponding remnants in the archaeological record.

ACKNOWLEDGMENTS

Subjects were housed in Laboratory of Comparative Ethology facilities at the National Institutes of Health Animal Center in Poolesville, Maryland. We thank Clara Menuhin-Hauser and Lily Westergaard for commenting on an earlier draft of this manuscript.

LITERATURE CITED

Anderson JR (1990) Use of objects as hammers by capuchin monkeys (*Cebus apella*). Folia Primatol. *54:*138–145.

Boesch C, and Boesch H (1993) Different hand postures for pounding nuts with natural hammers by wild chimpanzees. In Preuschoft H, and Chivers DJ (eds.): Hands of Primates. New York: Springer-Verlag, pp. 31–43.

Costello MB, and Fragaszy DM (1988) Prehension in *Cebus* and *Saimiri:* I. Grip type and hand preference. Am. J. Primatol. *15:*235–245.

Guthrie EA (1991) Variability of the primate trapeziometacarpal articulation: Description and functional significance. MA Thesis, Arizona State University, Tempe.

Jude J (1993) Manipulative behavior of hamadryas baboons. Senior Thesis, Arizona State University, Tempe.

Marzke MW, and Wullstein KL (1996) Chimpanzee and human grips: A new classification with a focus on evolutionary morphology. Int. J. Primatol. *17:*117–139.

Napier JR (1960) Studies of the hands of living primates. Pro. Zool. Soc. Lond. *134:*647–657.

Napier JR (1962) Fossil hand bones from Olduvai Gorge. Nature *196:*409–411.

Parker ST and Gibson KR (1977) Object manipulation, tool use and sensorimotor intelligence as feeding adaptations in *Cebus* monkeys and great apes. J. Hum. Evol. *6:*623–641.

Schick KD, and Toth N (1993) Making Silent Stones Speak: Human Evolution and the Dawn of Technology. New York: Simon & Schuster.

Susman RL (1994) Fossil evidence for early hominid tool use. Science *265:*1570–1573.

Susman RL (1995) Thumbs, tools, and early humans. Science *268:*589.

Toth N, Schick KD, Savage-Rumbaugh S, Sevcik RA, and Rumbaugh DM (1993) Pan the tool-maker: Investigations into the stone tool-making and tool-using capabilities of a bonobo (*Pan paniscus*). J. Arch. Sci. *20:*81–91.

Visalberghi E (1990) Tool use in *Cebus.* Folia Primatol. *54:*146–154.

Westergaard GC (1994) The subsistence technology of capuchins. Int. J. Primatol. *15:*899–906.

Westergaard GC, and Suomi SJ (1994) A simple stone-tool technology in monkeys. J. Hum. Evol. *27:*399–404.

Westergaard GC, and Suomi SJ (1995) The stone tools of capuchins (*Cebus apella*). Int. J. Primatol. *16:*1017–1024.

Westergaard GC, and Suomi SJ (1996) Hand preference for stone artifact production and tool-use by monkeys: Possible implications for the evolution of right-handedness in hominids. J. Hum. Evol. *30:*291–298.